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APPLICATION NUMBER: *60/505,538*
FILING DATE: *September 24, 2003*

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14230 U.S. PTO
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PTO/SB/16 (02-01)
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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (c).

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☒ *Additional inventors are being named on the ONE separately numbered sheets attached hereto*

TITLE OF THE INVENTION (280 characters max)

ALIGNMENT METHOD AND APPARATUS FOR PIXILATED DETECTOR

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☐ Customer Number [ ] → *Place Customer Number Bar Code Label here*

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ENCLOSED APPLICATION PARTS *(check all that apply)*

☒ Specification *Number of Pages* [11] ☐ CD(s), Number [ ]

☒ Drawing(s) *Number of Sheets* [4] ☐ Other (specify) [ ]

☒ Application Data Sheet. See 37 CFR 1.76

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT *(check one)*

☐ Applicant claims small entity status. See 37 CFR 1.27.

☒ A check or money order is enclosed to cover the filing fees

FILING FEE AMOUNT ($)

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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☐ No.

☐ Yes, the name of the U.S. Government agency and the Government contract number are: ____.

Respectfully submitted,

SIGNATURE [signature] Date [09/24/2003]

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TELEPHONE 216 861-5582 Docket Number: [PHUS030359USP]

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

This collection of information is required by 37 CFR 1.51. The information is used by the public to file (and by the PTO to process) a provisional application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 8 hours to complete, including gathering, preparing, and submitting the complete provisional application to the PTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, Washington, D.C., 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Box Provisional Application, Assistant Commissioner for Patents, Washington, D.C. 20231.

PROVISIONAL APPLICATION COVER SHEET

Additional Page

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Docket Number	PHUS030359	Type a plus sign (+) inside this box →	+

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ALIGNMENT METHOD AND APPARATUS FOR PIXILATED DETECTOR

Background of the Invention

The present invention relates to the diagnostic imaging systems and methods. It finds particular application in conjunction with the nuclear imaging systems using solid state detectors (SSD) and will be described with particular reference thereto. It will be appreciated that the invention is also applicable to the other imaging systems using pixilated imaging devices, and the like.

Diagnostic nuclear imaging is used to study a radionuclide distribution in a subject. Typically, one or more radiopharmaceutical or radioisotopes are injected into a subject. The radiopharmaceutical is commonly injected into the subject's bloodstream for imaging the circulatory system or for imaging specific organs, which absorb the injected radiopharmaceutical. A radiation detector is placed adjacent to the surface of the subject to monitor and record emitted radiation. Often, the detector is rotated or indexed around the subject to monitor the emitted radiation from a plurality of directions. These projection data sets are reconstructed into a three-dimensional image representative of the radiopharmaceutical distribution within the subject.

Commonly, each detector head includes an array of photomultiplier tubes (PMTs) facing a single large scintillation crystal. Each radiation event generates a corresponding flash of light that is seen by the closest photomultiplier tubes. Each photomultiplier tube that sees an event puts out a corresponding analog pulse. The analog pulses from the individual PMT's are digitized and combined to generate x and y spatial coordinates of the location of scintillation event on the crystal face.

In recent years, however, a use of solid state detectors in nuclear cameras has proved to be beneficial. Solid state detectors include a large array of individual detectors each of which utilizes the photoelectric effect to detect radiation.

More specifically, the received radiation photons liberate electrons from their orbits around atoms of the target material. The electrons are detected as an electrical signal.

Typically, solid state detector designs incorporate detector modules which each include a smaller array of individual detector elements, e.g. 256. The individual detector elements are few millimeters square. The detector modules, e.g. 50-60 in number, are installed in array on the motherboard, which is typically 20-40 centimeters on each side to define the active surface of the detector. In these designs, the module has contact pins, with which each module plugs into the motherboard. The electrical contact pins are thin and fabricated of electrically conductive metal. The pins tend to flex and bend slightly during insertion into mating holes in the motherboard permitting each module to skew slightly. Misalignments among the modules produce inaccuracies in the individual detector element grid that cause corresponding inaccuracies in the resultant image. The installation of the modules into a whole array with high tolerances to form a precisely rectangular grid of individual detector elements is difficult.

Nuclear cameras, particularly SPECT cameras, have a collimator that restricts the directions from which radiation can approach and strike the detector. The collimators have a grid of thin walls which overlie gaps or interfaces between individual detector elements. Although the collimator grids can be manufactured with high tolerances, skewed or shifted detector modules cause misalignment between the collimator and the detector elements. Even small misalignments place the collimator walls over larger portions of the active faces of some detector elements than others. Variations in the degree, to which detector element active faces are shadowed by the collimator grid, alters the effective size of some detector elements relative to others changing the relative amount of radiation received and degrading the resultant image.

There is a need for an alignment technique that would reduce the costs and complexity of alignment. The present invention provides a new imaging apparatus and method which overcomes the above-referenced problems and others.

Summary of the Invention

In accordance with one aspect of the present invention, a detector for a nuclear imaging system is disclosed. The detector comprises a plurality of sockets

which each support an array of individual detector elements. Each socket includes a plurality of electrical connectors and a socket alignment structure. The sockets are received on a circuit board that includes a plurality of electrical connection means which electrically connect with the electrical connectors, and a circuit board alignment structure which mates with the socket alignment structure to align the sockets and the individual detector elements to the circuit board. A means is used for mounting a collimator to the circuit board in alignment with the circuit board.

In accordance with another aspect of the present invention, a method of assembling a detector for a nuclear imaging system is disclosed. A plurality of sockets, which each include an array of individual detector elements, a plurality of electrical connectors, and socket alignment structures, is inserted into a circuit board which includes a plurality of electrical connections which electrically connect with the electrical connectors as the sockets are inserted, and circuit board alignment structures, which mate with the socket alignment structures as the socket is mounted to align the arrays of detector elements with the circuit board and each other. A collimator mounting means is mounted and aligned to the circuit board such that the collimator mounting means is aligned with the arrays of detector elements.

One advantage of the present invention resides in improving performance of detector by precisely aligning individual receptive elements to the openings in collimator.

Another advantage of the present invention resides in using separate non conducting alignment structures thus reducing cost and complexity of alignment.

Still further advantages and benefits of the present invention will become apparent to those of ordinary skill in the art upon reading and understanding the following detailed description of the preferred embodiments.

Brief Description of the Drawings

The invention may take form in various components and arrangements of components, and in various steps and arrangements of steps. The drawings are only for purposes of illustrating the preferred embodiments and are not to be construed as limiting the invention.

FIGURE 1 is a diagrammatic illustration of nuclear imaging system in accordance with the present invention;

FIGURE 2 is a diagrammatic illustration of a detector;

FIGURE 3 is a diagrammatic illustration of a portion of a substrate; and

FIGURE 4 is a diagrammatic illustration of a portion of a substrate and a frame.

Detailed Description of the Preferred Embodiments

With reference to FIGURE 1, a nuclear imaging device **10** typically includes a stationary gantry **12** that supports a rotating gantry **14**. One or more detector heads **16** are carried by the rotating gantry **14** to detect radiation events emanating from a region of interest or examination region **18**. Each detector head includes a two-dimensional array of detector elements or detector **20**. The detector arrays are preferably solid-state detectors, which convert gamma radiation directly into electrical charge. Each head **16** includes circuitry **22** for converting each radiation response into a digital signal indicative of its location (x, y) on the detector face and its energy (z). A collimator **24** controls the direction and angular spread, from which each detector element of the array **20** can receive radiation.

Typically, an object to be imaged is injected with one or more radiopharmaceutical or radioisotopes and placed in the examination region **18** supported by a couch **26**. The presence of the radiopharmaceuticals within the object produces emission radiation from the object. Radiation is detected by the detector heads **16** which are, preferably, angularly indexed or rotated around the examination region **18** to collect the emission data from a plurality of directions. The projection emission data (x, y, z) and an angular position (θ) of each detector head **16** around the examination region **18** are stored in a data storage **28**. A reconstruction processor **30** processes the event and detector orientation data from the data storage **28** into a volumetric image representation. The image representation is then stored at a volume image memory **32** for manipulation by a video processor **34** and display on an image display **36** such as a video monitor, printer, or the like.

With reference to FIGURE 2, the detector **20** includes a substrate or a circuit board **40**, on which detector modules **42** are mounted in a close packed tile arrangement. Each detector module **42** includes a socket **44** and a crystal array **46**. Each crystal array **46** is preferably divided into 256 individual detector elements or pixels **48**. The substrate **40** includes rectangular openings **50**. A plurality of holes or pin sockets **52** is disposed about the openings **50** to electrically connect with the detector modules **42**. More specifically, each module's socket **44** employs electrical connectors or pins **54** disposed about its perimeter. The electrical connector pins **54** are inserted into the plurality of mating pin sockets **52** to establish the electrical connections with the crystal **48** and the associated electrical components disposed on the substrate **40** or in the detector head **16**.

With continuing reference to FIGURE 2, the detector **20** further includes a frame **60** that is mounted to the substrate **40** to support the collimator **24**. The collimator **24** includes a lead grid **62** that is made from pieces that mate together to make a square matrix of apertures **64**, which spans the entire array of detector modules. As explained in greater detail below, the frame **60** positions the collimator **24** such that vanes **66** that define each square collimator aperture **64** are aligned with the gaps or interfaces **68** between individual detector elements **48** on the circuit board **40**.

With reference to FIGURE 3, each socket **44** includes contact portion **70** at which the crystal array **46** is electrically connected to the electrical contact pins **54**. Each socket further includes two or more alignment pins **72**, positioned diagonally from each other. Corresponding mating alignment openings or holes **74** are provided on the substrate **40**. The alignment pins **72** are preferably made of high strength steel, but other rigid, hard to deform materials are also contemplated. The placement and cross section of the alignment pins **72** and the alignment openings **74** are manufactured with high precision. The interaction of the alignment pins **72** and holes **74**, as the sockets **44** are inserted into the circuit board **40**, precisely aligns the detector modules **42** and the individual detector elements **48**. Of course, the alignment mechanism might be reversed, with the pins provided on the substrate and mating openings on the socket.

With reference again to FIGURE 2 and further reference to FIGURE 4, the frame **60** has a rectangular face **80** having a longer dimension **82** and a shorter dimension **84**. Four alignment openings are defined through the frame **60** and match with alignment openings **86** defined in the substrate **40**. More specifically, a pair of primary frame alignment openings **88** is defined in the shorter dimension **84**, and a pair of secondary frame alignment openings **90** is defined in the longer dimension **82**. Typically, only one pair of frame alignment openings is used to mount the frame **60** to the substrate **40**, to account for the effect of thermal dilatation. Preferably, the frame alignment openings **88** positioned along the shorter dimension **84** are used to mount the frame **60** to the substrate **40**, although both pairs are used in the alignment process. The system is constructed from different materials, each of which expands and contracts at different rates. Having the alignment structures positioned across the shorter dimension **84** reduces the effect of thermal stress. Of course, if the materials used in the system are changed to reduce thermal stress, the secondary frame alignment openings **90** positioned about the longer dimension **82** might be used.

With continuing reference to FIGURES 2, 3 and 4, once the frame **60** is aligned with the circuit board **40**, it is also aligned with the detector modules **42** and the individual detector elements **48**. To align with the collimator **24**, the frame **60** has inside surfaces **92** around its central opening that mate with exterior surfaces **94** of the collimator **24**. Alternatively, the collimator **24** can have a flange with alignment and mounting pins **96** that are received in alignment and mounting apertures **98** in the frame. In this manner, the collimator apertures **64** are fixedly aligned with the individual detector elements **48** with a tolerance of +/-10 micron.

The invention has been described with reference to the preferred embodiments. Modifications and alterations may occur to others upon a reading and understanding of the preceding detailed description. It is intended that the invention be constructed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.

Having thus described the preferred embodiments, the invention is now claimed to be:

1. A detector **(20)** for a nuclear imaging system **(10)**, the detector comprising:

a plurality of sockets **(44)** which each support an array of individual detector elements **(48)**, each socket including:

a plurality of electrical connectors **(54)**, and

a socket alignment structure **(72)**;

a circuit board **(40)** for receiving sockets **(44)**, which circuit board includes:

a plurality of electrical connection means **(52)** which electrically connect with the electrical connectors **(54)**, and

a circuit board alignment structure **(74)** which mates with the socket alignment structure **(72)** to align the sockets **(44)** and the individual detector elements **(48)** to the circuit board **(40)**; and

a means **(58)** for mounting a collimator **(24)** to the circuit board **(40)** in alignment with the circuit board **(40)**.

2. The system as set forth in claim 1, wherein the socket alignment structure **(72)** and the mating circuit board alignment structure **(74)** includes rigid pins and apertures of like cross-section.

3. The system as set forth in claim 2, wherein the rigid pins are not used for transmitting electrical signals between the sockets **(44)** and the circuit board **(40)**.

4. The system as set forth in claim 1, wherein the collimator mounting means **(58)** includes a frame **(60)** and further including:

an aligning means **(86, 88)** for aligning the frame **(60)** and the circuit board **(40)**.

5. The system as set forth in claim 4, wherein the individual detector elements (48) are separated by interfaces or gaps (68) and wherein the collimator (24) includes mechanical elements (66) which define a plurality of apertures (64), the mechanical elements (66) being aligned with the interfaces or gaps (68) such that the apertures (64) are centered on and aligned with the individual detector elements (48).

6. The system as set forth in claim 4, wherein the aligning means (86, 88) includes:

at least two alignment holes (88) defined in the frame (60), and

at least two matching holes (86) defined in the circuit board (40).

7. The system as set forth in claim 5, wherein the frame (60) has a rectangular face (80) including:

a longer dimension (82), and

a shorter dimension (84),

the at least two frame alignment holes (88) being disposed along the shorter dimension (84) to reduce an effect of thermal dilatation.

8. The system as set forth in claim 1, wherein the socket alignment structures (72) includes rigid pins positioned diagonally from each other.

9. The system as set forth in claim 8, wherein the connectors (54) are pins of relatively soft metal that tend to deform as the sockets (44) are received on the circuit board (40).

10. A method of assembling a detector (20) for a nuclear imaging system (10) comprising:

inserting each of a plurality of sockets (44), which each include an array of individual detector elements (48), a plurality of electrical connectors (54), and socket alignment structures (72) into a circuit board (40) which includes a

plurality of electrical connections **(52)** which electrically connect with the electrical connectors **(54)** as the sockets are inserted, and circuit board alignment structures **(74)**, which mate with the socket alignment structures **(72)** as the socket is mounted to align the arrays of detector elements **(48)** with the circuit board and each other; and

aligning and mounting a collimator mounting means **(58)** to the circuit board such that the collimator mounting means is aligned with the arrays of detector elements **(48)**.

11. The method as set forth in claim 10, wherein the collimator mounting means includes a frame **(60)** which mounts a collimator **(24)** in fixed alignment thereto, hence to the circuit board **(40)** and the individual detector arrays **(48)**.

12. The method as set forth in claim 11, wherein the individual detector elements **(48)** have interfaces **(68)** therebetween and the collimator has mechanical elements **(66)**, which define apertures **(64)**, the mechanical elements being aligned with the individual detector element array interfaces.

13. A detector **(20)** for a nuclear imaging system **(10)**, the detector comprising:

a substrate **(40)** including a plurality of sets of electrically conductive holes **(52)** and alignment holes **(72)** of precise cross section; and

a plurality of detector modules **(42)** each detector module including a plurality of electrically conductive connection pins **(54)** which are sufficiently soft to tend to bend and rigid alignment pins **(74)** of the precise cross section, each set of holes being configured to receive one of the modules **(42)**.

14. The apparatus as set forth in claim 13, wherein each detector module **(42)** includes:

individual detector elements **(48)** which are electrically connected to the electrically conductive connector pins **(54)**, the individual detector elements being

mounted in a rectangular array separated from each other by a rectangular grid of interfaces **(68)**.

15. The apparatus as set forth in claim 13, wherein the substrate **(40)** defines a plurality of substrate alignment holes **(72, 86)** and further including:

a frame **(60)** which defines alignment holes **(88, 90)**, which align with the substrate alignment holes **(86)**.

16. The apparatus as set forth in claim 15, wherein the frame **(60)** has a rectangular face **(80)** which includes:

a longer dimension **(82)**, and

a shorter dimension **(84)**; and

the alignment holes including two alignment holes **(88)** defined in the shorter dimension **(84)** to reduce an effect of thermal dilatation.

17. The apparatus as set forth in claim 15, wherein the frame **(60)** includes a collimator mounting means **(92, 98)** for mounting the collimator **(24)** in precise alignment therewith, the collimator including:

radiation blocking element **(62)** that form a rectangular grid which overlays the interface grids **(68)** of the individual detector elements **(48)** which are mounted to the substrate **(40)** when the collimator is mounted in and aligned with the frame that is aligned with the substrate **(40)**.

ALIGNMENT METHOD AND APPARATUS FOR PIXILATED DETECTOR

Abstract of the Disclosure

A detector (20) for a nuclear imaging system (10) includes a plurality of sockets (44) which each support an array of individual detector elements (48). Each socket (44) includes a plurality of electrical connectors (54) and socket alignment structures (72). The sockets (44), carrying the detector elements (48), are installed onto a circuit board (40). The circuit board (40) includes a plurality of electrical conductive openings (52) which electrically connect with the electrical connectors (54) and alignment structures (74) which mate with the socket alignment structures (72) to align the sockets (44) and the individual detector elements (48) to the circuit board (40). A collimator (24) is mounted and aligned to a frame (60). The frame (60) and the circuit board (40) each include aligning structures to align the collimator (24) to the circuit board (40) and the individual detector elements (48).

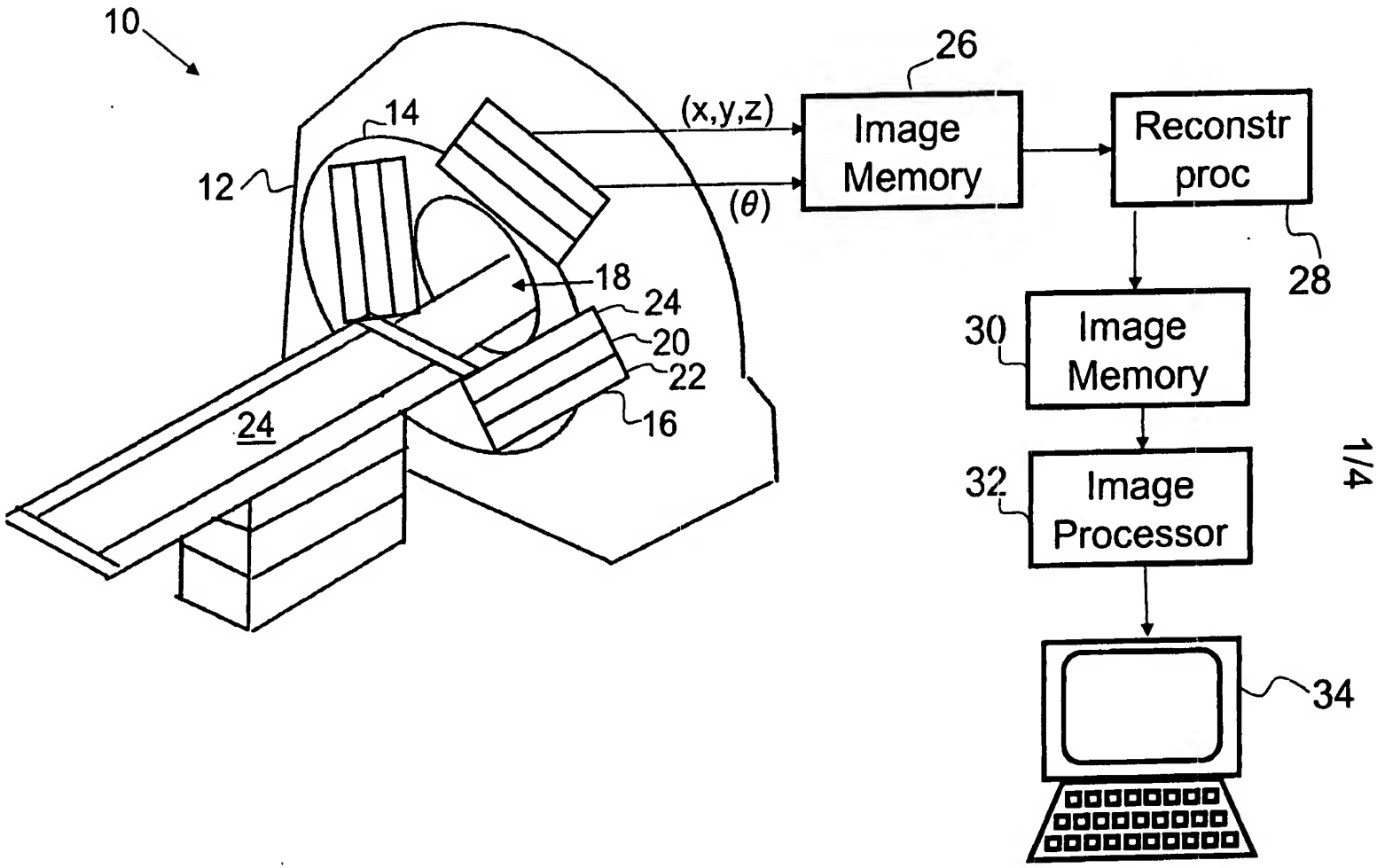
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FIG 1

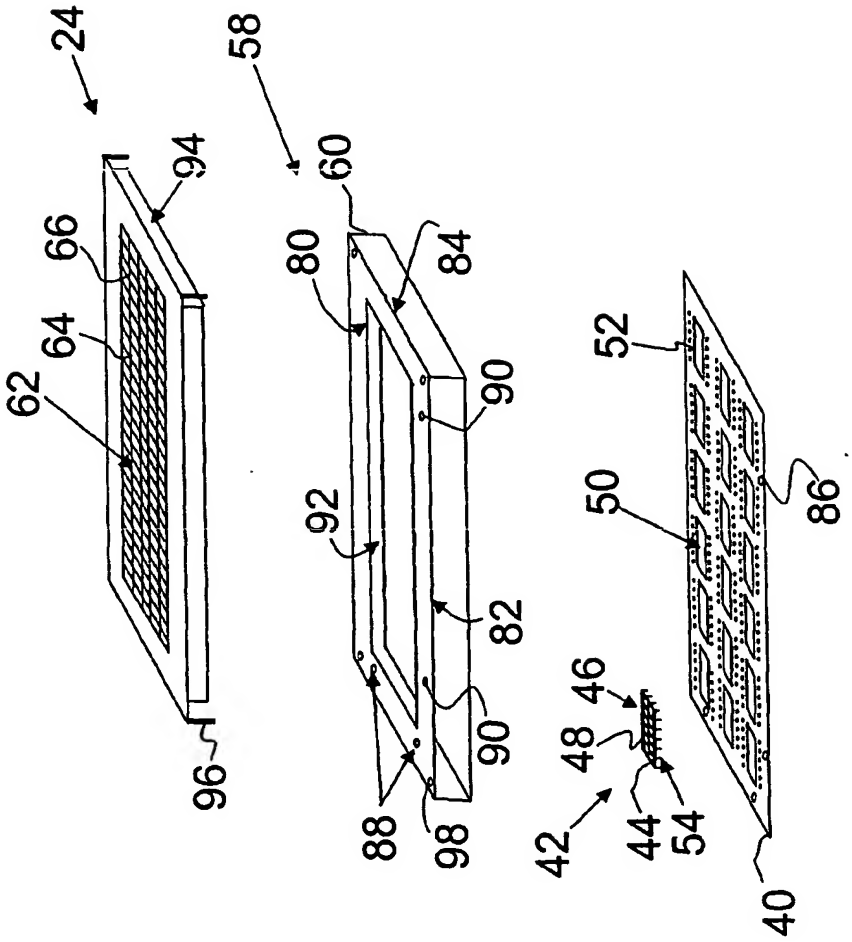
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FIG 2

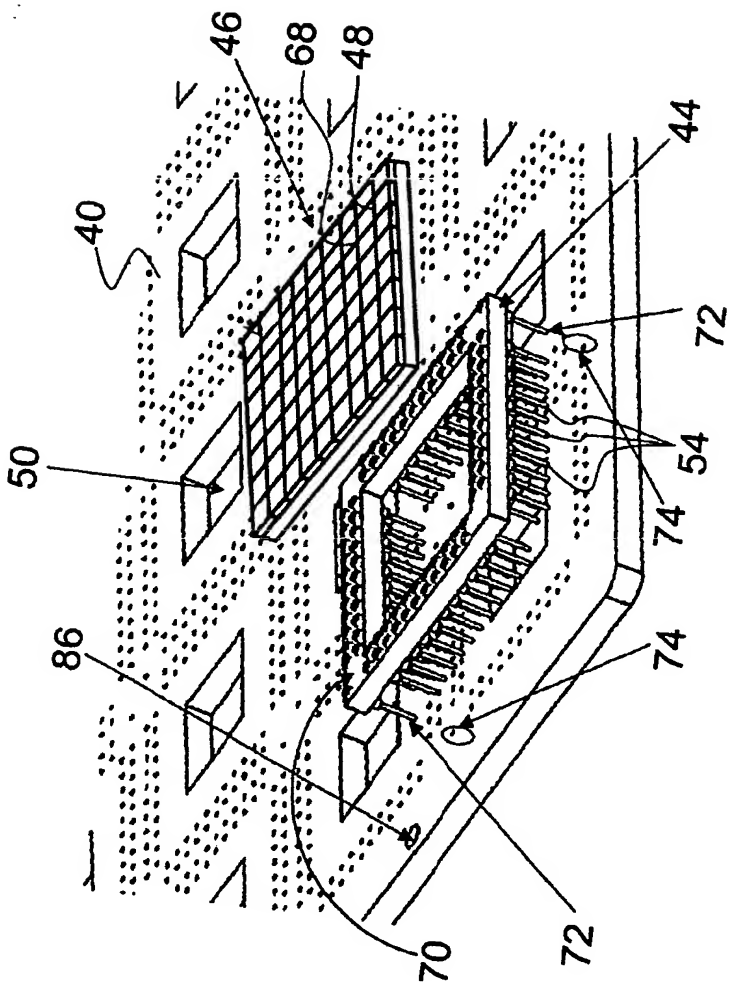

FIG 3

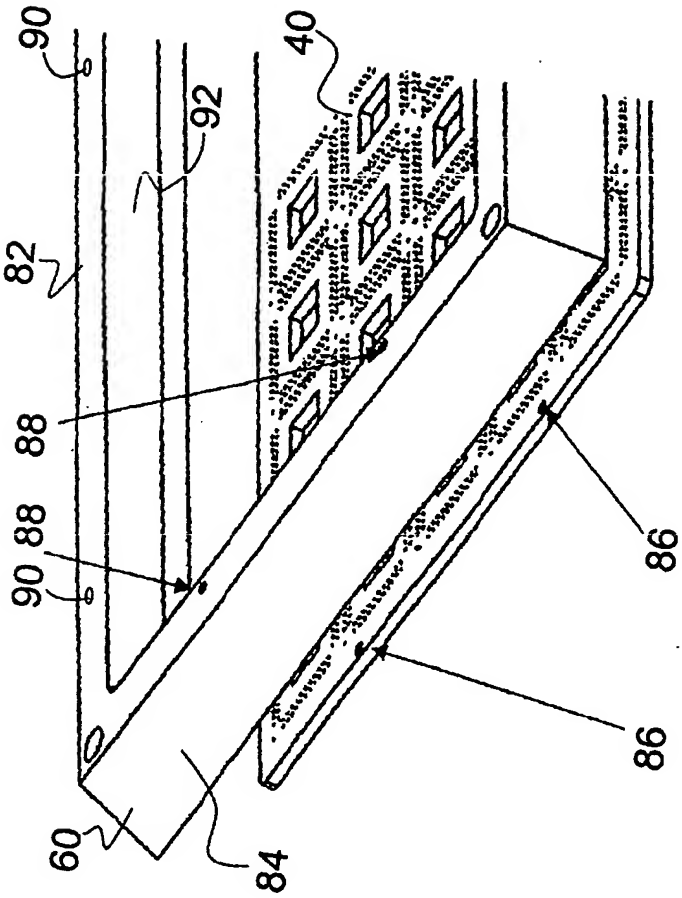

FIG 4

 Attorney's Docket No. PHUS030359USP (#704005)

APPLICATION DATA SHEET

Mail Stop: Provisional Patent Application
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APPLICATION DATA SHEET

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